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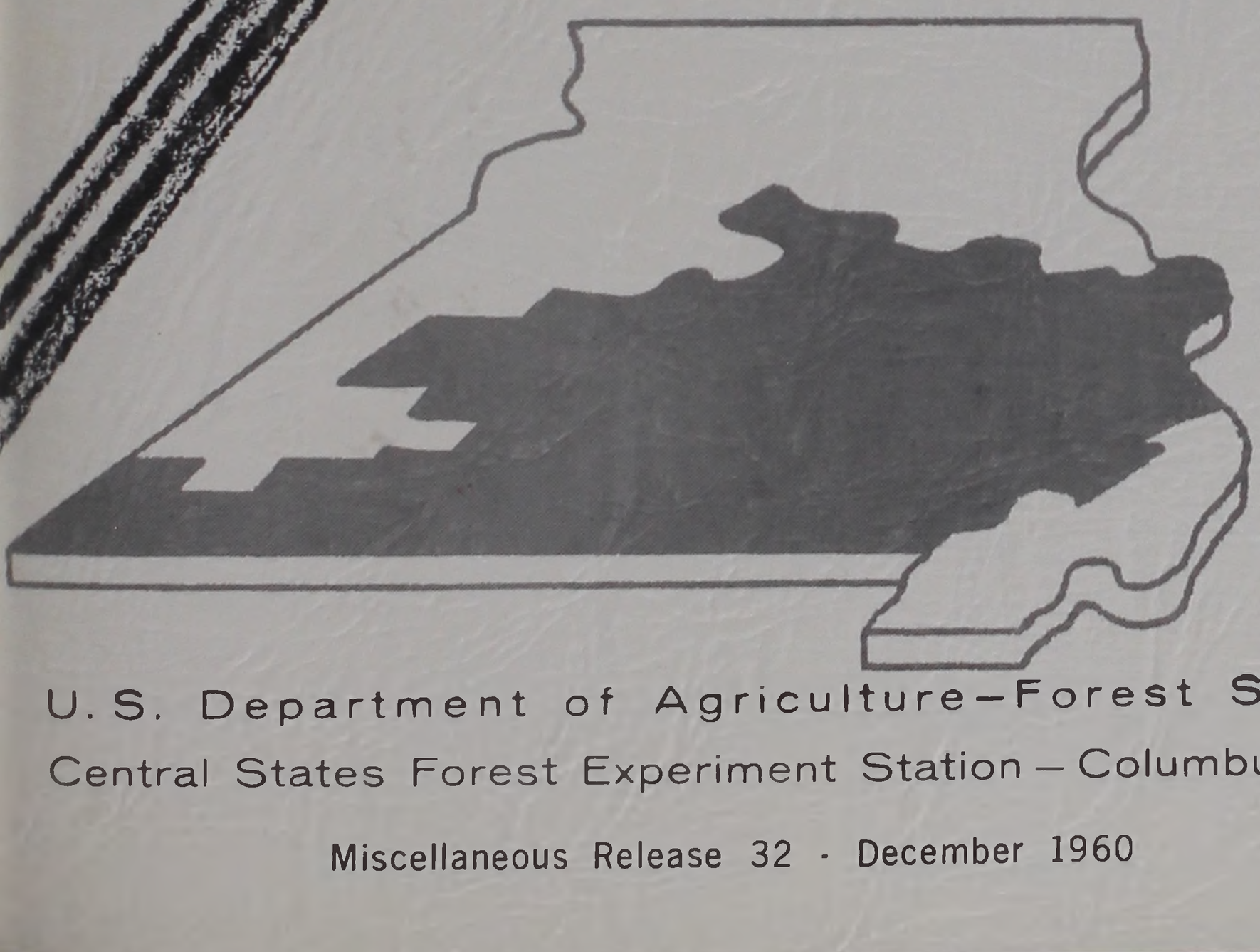
FOREST and RANGE FIRE PROBLEMS of the MISSOURI OZARKS

John S. Crosby



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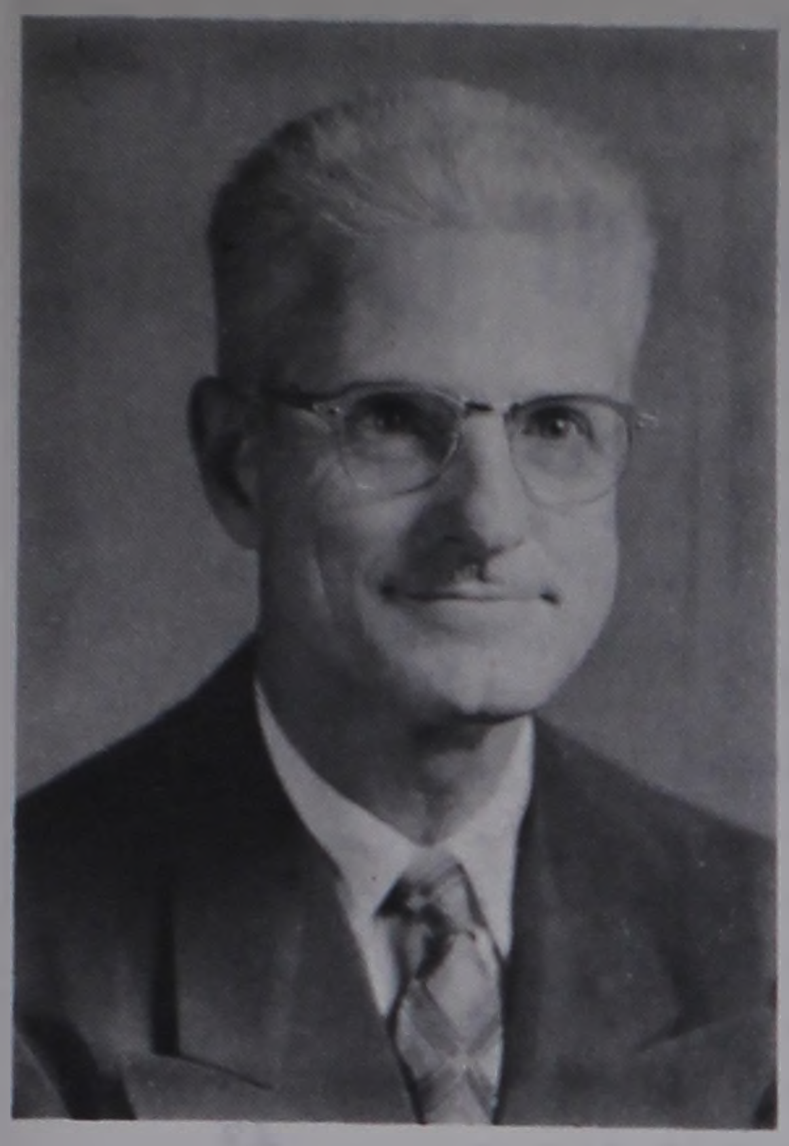

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FOREST and RANGE FIRE PROBLEMS of the MISSOURI OZARKS

John S. Crosby

Missouri's 15.2 million acres of forest are producing only one-fifth to one-third of their potential because of frequent forest and range fires and other misuses. These forests are one of the State's most important renewable resources. They occupy more land area than any other crop. Moreover, about 80 percent of the forest (12.2 million acres) lies in the rough Ozark Region where most of the land is better suited to forests than any other crop.

About two-thirds of the lumber used in Missouri is imported, and yet people must continually migrate from the forested region to find employment. If forests are to contribute their proper share to the economy of the area, it is necessary to stop the misuses and improve the management of forests and utilization of forest products. Adequate protection from fire is the first step.

The Missouri Conservation Commission and the U.S. Forest Service, cooperating with many large and small landowners, now provide organized protection for three-fourths of Missouri's forest land. The annual cost of this protection is more than $900,000. In spite of this effort, as many as 3,500 fires burn as many as 100,000 acres of protected area in a year. Losses caused by these fires must be added to the cost of protection to get the total cost of forest fires.

Almost all forest fires in Missouri are man-caused and therefore should be preventable. Fire control needs to be intensified within existing protection districts and extended to the remaining unprotected areas. This is a big job and, because forestry and fire control are relatively new in Missouri, there are many problems encountered by forest managers on which research is needed.

The purposes of this paper are to list and discuss the broad problems of fire control and the factors contributing to these problems, classify them as to their relative importance, and show on which problems work has been started by the U.S. Forest Service and is planned for the near future. This analysis of forest and range fire problems in the Missouri Ozarks will help guide the fire research program carried on by the Forest Service in the Missouri area.

The fire research project of the Central States Station is centered in Missouri and further concentrated in the Ozark Region of that State (fig. 1) because forests are abundant and most all the fire problems are encountered there. The project is expected to serve the other states in the central region as well, for many of the problems on which research can be done will have direct application to the same problems in Ohio, Indiana, Illinois, Kentucky, and Iowa.

Problems are included if they have a close relationship to fire control in the area. However, not all problems listed will be considered in the work program. The overall Forest Service plan for forest fire research includes three fire research laboratories. These laboratories are now either in operation or in active preparation for use. Other Forest Service research stations at which fire research is conducted, of which this Station is one, are considered to be primarily applied research stations. Thus, work on fundamental research will be properly referred to, or begun at the fire laboratories. Some problems involving a large amount of cooperation with other fields such as timber management, range management, or game management will have to be conducted cooperatively. Again some types of research can best be undertaken by other groups or agencies and will not be included in the program. The size of the project will, of course, impose definite limits on the areas and extent of work undertaken.

In the central states fires are numerous and often related to methods of land use. An appreciation of the residents' point of view and the natural features of the area is the beginning of successful fire prevention. So, an effort has been made here to review the background for the prevalent custom of "woods" burning.

In the immediate future, assuming no let-down in suppression activities, more can be gained in fire control by reducing the large number of fires than in overcoming technical fire-suppression problems

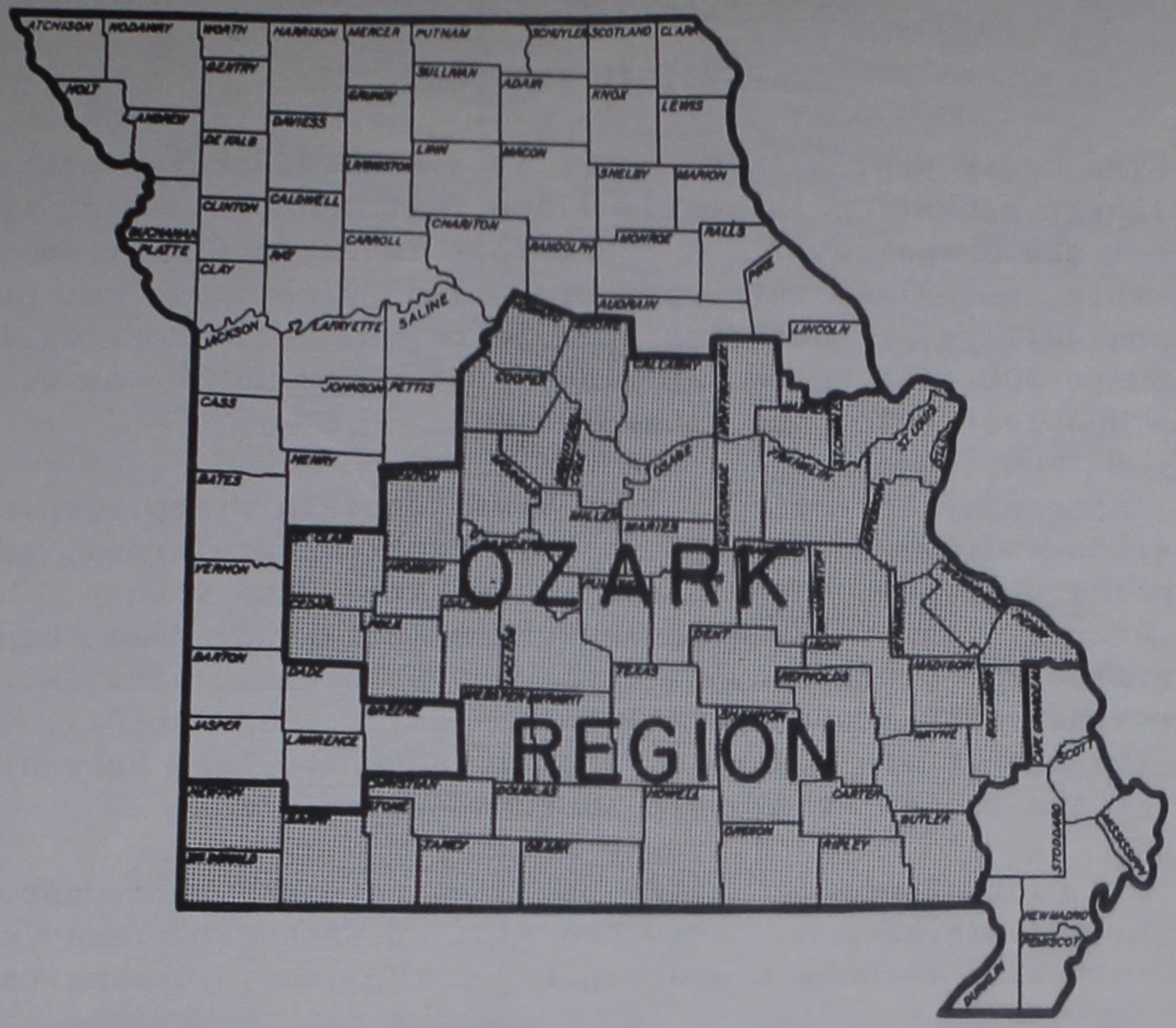

Figure 1.--The Ozark Region of Missouri.

Suppression is often difficult and always dirty, but is seldom extremely complicated in the common Ozark fuels. Extra-period fires are rare. As fires become less numerous however, better technical knowledge of fire behavior, fuels, and suppression methods will become the backstay of improvement in fire control. Both programs need to be pursued aggressively for in some places the transition stage has already been reached.

DESCRIPTION OF THE REGION

PHYSICAL FEATURES

The Ozark Region in Missouri is a much-dissected plateau. The highest elevation is nearly 1,800 feet and the lowest is about 300 feet above sea level. A 1,500-foot range in elevation is not remarkable, but since this very old upland area is so cut up by numerous valleys, it contains much rough country. Most valleys are 100 to 300 feet below the ridges but a few may be as much as 700 to 800 feet below the ridges.

Topography is varied. Some areas contain steep slopes and narrow valleys and ridges; other areas feature broad, gently undulating plateaus; and, in the vicinity of Iron County, there is an area of granite outcropping characterized by dome-shaped mountains. The topography of most of the forested area is rough and provides many slopes on which fire may travel rapidly. But since the slopes are generally short, there are many natural lines (valleys and ridges) that help in suppressing fires.

The Ozark Region contains parts of several watersheds. The main streams have a continuous flow of water, but many of the numerous feeder streams are dry part of the year, flowing only during or after heavy rains. Many springs dot the Ozarks. Big Spring, one of the largest single springs in the world, is located here. Because many of the Ozark streams are spring-fed and have forested watersheds, they are usually very clear. But because of the difficulty of getting water to fires, water is not extensively used for fire suppression.

The soils of the area, mostly of the Clarksville series, are typically stony and medium to low in fertility. Many of these stones are hard, sharp-edged chert. The soils on the hillsides and narrow ridges have the highest chert content, whereas the soils on the broad ridges and valleys frequently have more loam or silt. The soils have poor structure, are low in organic matter, and are droughty. Soils having these characteristics are not well suited for farming but can support forests. Most of the cultivated land is in the narrow valleys and on the broad undulating plateaus, though isolated fields are found on narrow ridges and even on some rather steep hillsides (fig. 2).

Most of the main roads have been built on ridges. Many other ridges and main valleys have trails of some kind varying from hardly more than a footpath to a main thoroughfare, and there are frequent connecting trails between ridges and valleys. This is significant, for it makes the whole area much more accessible than would be expected from the rough appearance of the country.

Figure 2.--Aerial photo showing typical features of Missouri Ozark landscape. State highway follows along main ridge. Trails lead off secondary ridges. Roadways lead off main highway into cleared fields in valley bottoms and continue down valley to other farms. Abandoned ridge or valley fields beginning to fill in with hardwood sprouts. Fields and other evidences of habitation are imbedded in a matrix of forest land.

The low-class roads are mostly in bad repair, having steep grades and unbridged stream crossings and are not well suited for travel by ordinary passenger vehicles. Although a pickup truck will go over many of these roads, the four-wheel-drive jeep is a more dependable means of traveling the back country roads and trails and has become a common means of forest transportation.

COVER

Originally the State of Missouri had about 31 million acres of forest land. Clearing, primarily for pastures and cultivation, has reduced this more than half. There are 22.2 million acres of land in the Ozark Region (2).[1/] Of this total, 12.2 million acres (55 percent) is forested. Krusekopf (3) classed as nonarable 54 percent of the central Ozark area because of slope or rockiness. Although the forested and nonarable areas are not identical, for the most part forests occur on nonarable land. Changes from forest to nonforest are expected to be balanced by changes from nonforest to forest so that little change in the total area of forest is expected in the near future.

According to the Forest Survey (2), forest types in which oak species predominate occupy 88 percent of the forest area in the central Ozarks and 65 percent in the river-border counties. Oak-pine and pine types make up 8 percent of the forest area. Bottomland hardwoods, mixed hardwoods, and cedar-hardwood types make up the remainder.

The forests of the Missouri Ozark Region as of 1947[2/] contained an estimated 8.7 billion board feet of merchantable sawtimber. Average net volume of merchantable sawtimber was only about 700 board feet per acre and one-third of the gross volume was in cull trees and trees of noncommercial value. The growth rate averaged only about 40 board feet per acre per year. Both the present volume and growth rate are far below the productive capacity of the land. Some improvement is expected to be shown by the new Forest Survey data now being processed. Preliminary figures indicate an increase in sawtimber volume of about 8 percent in the eastern Ozarks.

The kinds of plants growing on the land have a direct bearing on fuels and indirectly on many other fire-control problems. Because hardwood tree species form the greatest part of the forest cover, there is a remarkable consistency in the kind of surface litter fuels (fig. 3). There is much less uniformity in the amount of fuel because of fire and cutting history and because of site factors. Most of the stands are of low quality with many cull and dead trees which, as fuels, cause difficulty in fire suppression.

Nonforest land vegetation is also important to fire control. Here the common fuels are grass and weeds - flashy fuels in fall, winter, and spring (fig. 4). The nonforest land is well distributed throughout the forest land. It is here the people live. People start fires, so fires on nonforest land must be controlled to protect adjacent forest land.

1/ Numbers in parentheses refer to Literature Cited, page 47.
2/ Last available data. A resurvey is now in progress.

Figure 3.--Hardwood leaf litter is the most common surface fuel found in the Missouri Ozarks. Hardwood stands similar to the above are common in the Region.

Figure 4.--Grasses mixed with weeds, low shrubs, and sprouts are the fuels commonly found in nonforest land and in open forests or woods pastures. The quantity of fuel may be greatly reduced by grazing.

CLIMATE

The Ozark Region has a continental-type climate. The average January temperature ranges from 30 to 36 degrees and the average July temperature ranges from 76 to 80 degrees. Record extremes of temperature for the Region range from -40 to 118 degrees Fahrenheit. Below zero temperatures are uncommon and of short duration. The ground is only frozen for short periods and the frost-free period is a full 6 months.

Precipitation averages from 40 to 50 inches per year. Normally, about 60 percent of the annual precipitation falls during the warm half of the year, but this ratio may vary greatly. The highest average monthly precipitation occurs in the months of April, May, June, and September and the lowest in November, December, January, and February. Mean monthly precipitation in the Region ranges from a low of 1.5 inches in February in the north and west parts to 5.5 inches in May in the southwest part (1). Very heavy rain often occurs locally in storms. Twelve inches of rain fell in 42 minutes at Holt, Missouri, June 22, 1947, which is a world's point rainfall record. Snowfall, which averages about 18 inches but varies from 5 to 40 inches, usually does not accumulate more than a few inches at a time, and the accumulation from one storm is usually melted before another storm follows. There is a gradual decrease in total precipitation from southeast to northwest across the State, and although the forested part of the State lies well within the humid portion of the United States, the prairie adjacent to the region borders the sub-humid region.

Although these figures depict the average values for temperature and precipitation, climatologists point out that variations from the average are the rule. The average year has probably never occurred. Day-to-day changes in weather may be great. Although severe, prolonged droughts are infrequent, hot, droughty periods frequently occur in summer. The distribution of rainfall is very important to fire control.

The climate is such that fires may occur in every month of the year in Missouri, but there are two peaks in fire occurrence. The major peak is in late winter and early spring--February, March, and April--and the other is in the fall--September, October, and November. In the spring period the air is generally dry and winds are strong. Conditions during the fall season are somewhat similar though usually less severe. However, very serious conditions may develop in the fall months. During both periods litter and grass fuels are most abundant and very flammable when dry. During the summer the air is more humid, winds are lighter except in storms, and the fuels are better protected by the forest canopy. Nevertheless, fuels dry rapidly and frequently a high potential for fires exists in the summer. Since custom is against summer burning, fires are fewer and mostly accidental, and summer is rarely a serious fire season.

PEOPLE AND FIRES

Why is forest and range burning so prevalent in this Region? There is no one simple answer. Because almost all fires are man-caused, the answer lies with the people who live here--their attitudes, occupations, customs, and economic status. These in turn have been molded by the quality and configuration of the land, the climate, and the vegetation. More specifically, the answer involves the methods of making a living on poor land more than half of which is forested. The forests are neither contributing much to their livelihood nor is the potential value of the forest generally recognized or demonstrated. Fire is used to fight the forest in an attempt to use the land for other purposes. Forest fires are in the middle, both a cause and a result of a conflict in the use of land. Fire control is a prerequisite to good land use, yet satisfactory fire control is not likely to be accomplished without great improvement in land use.

The population of the Missouri Ozarks is predominately rural. Towns are few and small and are primarily rural trading centers. The people generally have strong ties with their home country and seem to find it sufficient to their needs. They migrate more to find jobs than because of dissatisfaction with their living place. They are proud and independent, not accustomed to luxury nor particularly demanding it. They are used to hardships and staunchly defend their personal freedoms. They are self-reliant. They hold to old customs and methods so that changes take place slowly. They are hospitable though somewhat slow to accept strangers.

Survival on rough, droughty, infertile, rocky land calls for stamina, frugality, and resourcefulness. These were qualities of the frontiersmen, farmers, and woodsmen who settled here. But in the Missouri Ozarks these qualities had to be sharpened and perpetuated to insure survival. They have persisted to a greater degree than in many other areas more favorably situated for agriculture.

In the Missouri Ozarks "success" is more apt to be measured by personal qualities than by affluence. Among some groups it is a matter of taking the things at hand and making the best available use of them, being industrious and finding happiness in living. Although the living level may be low in terms of conveniences, luxuries, and education, the family can still be respected in the eyes of the community if its members possess the approved personal qualifications.

The land most suitable for cultivation is scattered in small tracts frequently separated by large areas of forest. Habitations generally are near the arable land so families are widely scattered

emphasizing the need for personal self-reliance and the development of individuality. Scattering the small number of people over a large area also scatters the chances for fires over a large area.

Poor-quality land and lack of capital have discouraged intensive cropping for high unit yields and encouraged extensive use of all land for a lower return per acre by the least expensive methods. Average income per farm family in the Region ranges between $900 and $2,000 per year. Farm income is higher on the fringes of the Region and above $3,000 in a few river-border counties.

The lineal land surveys developed rectangular farm units that included relatively large amounts of hilly forested land and small amounts of arable land (fig. 2). The predominating hardwood forests were undoubtedly quite open stands with large quantities of grass in them at the time of settlement (fig. 5). Extensive use of land for cattle and hogs was practical. Moreover, no area limits were known for this use. Fences were exclosures, not enclosures.

However, the reduction of browsing animals, increase in grazing animals, cutting of timber, and burning of the forest land all contributed towards increasing the reproduction and sprouting of trees in woods and grasslands. Increasing the density of woody cover was definitely undesirable to the settlers who needed the native grass and open fields. So the farmers' battle with hardwood sprouts began early and has been unrelenting. Fire has been his primary weapon.

Figure 5.--This old-growth hardwood stand has little reproduction and may be similar to many of the stands found in the Missouri Ozarks by the settlers.

Hardwood species now grow on 88 percent of the Ozark forested area. Although hardwoods have provided useful products, employment, and income for many residents, they have been high-graded, burned, grazed, and cussed. The objective was to get rid of the "brush." But Missouri hardwoods, like Missouri people, are hard to defeat. The hardwoods sprout and persist after repeated abuses, though tree quality decreases rapidly. Hardwoods have been unpopular with the people because of low market price and their preference for cleared land. Now, even though there is a good market for quality hardwoods, past abuses have so reduced the supply of good-quality trees that the return per acre is very low and interest in management and protection of the forests is not easily stimulated.

Shortleaf pine, however, has received a measure of respect. Since settlement days, pine has been sought for building. Being less common than hardwoods and more useful for building, pine has been considered a forest tree whereas hardwoods make woods or "brush." Even today young pine, especially planted pine, is respected and not so often burned.

Extensive land use led to a proprietory feeling by the residents towards wild land owned by absentees. The "use-rights" to wild land included range, hunting, and fishing, and were often extended to timber ("grandmawing"). Open range still persists in several counties and decreases very slowly. But timber trespass is declining under increased supervision of forest land.

Open range seemed to carry with it the prerogative to burn the woods; otherwise, "what good is the range?" "Use-rights" were exercised by resident farmowners and others on adjacent forest land especially that of non-resident owners regardless of the owners' intent of use. However, until recently, the larger timber companies made no attempt to manage forest properties after cutting so the use-rights have not generally been contested.

Woods burning became traditional in the Region (fig. 6). Though many reasons can be cited, the most plausible reason for woods burning seems to have been to increase forage production. Burning destroys old unpalatable straw, exposes green forage on the range earlier in the spring, provides at least a temporary increase in soil fertility, helps keep the hardwood sprouts temporarily in check, and prevents litter from accumulating. These effects have been considered highly desirable.

The importance of woods range is evident since one-half to two-thirds of all the farmland used for grazing is wooded, most all open range land is wooded, and over three-fourths of farm income is obtained from livestock.

Figure 6.--Woods burning has long been a custom in the Ozarks. Nearly all forest land was burned on a 3-to-5-year rotation in the past and some still is. This practice is incompatible with good forest mangement.

Practically all the woodlands as well as some fields used to be burned--and some still are--in a 3-to-5-year rotation. The practice was approved by most of the resident people. Burning was considered not only right but necessary.

The people may have prevented the woods from completely eliminating grass from the land by burning, but they have been unable to fully utilize the land for range because they could not eliminate tree competition with the use of fire alone. Moreover, the effects of fire that would improve forage, arrested the desirable growth of forest trees. Overgrazing and fire have frequently rendered the range and the forest almost useless. Thus neither the potential range nor the potential forest resource is allowed to develop (fig. 7). The land and vegetation became progressively poorer and income progressively smaller. That burning may be a poor practice--that burning may damage the forest stand--is all beside the point. The prevailing practice was to get as much return this year from the extensive use of woodlands for range, and to use the cheapest means to make a little more grass available for the stock.

Much progress has been made in preventing and controlling fires during the past 27 years. There is evidence now of a growing acceptance of fire control by an increasing number of local residents. Acceptance of fire control is an essential for effective fire prevention. This group is still a minority. Perhaps most people are still indifferent--not satisfied that fire control is good, but willing to go along with it. Many fires are still caused by a small group who feel burning is necessary or who simply defy the law.

The Missouri Ozark people who have opposed fire control have not done so without reason. They have been caught between two ideologies. One, to burn the woods has the strength of tradition. The other, to protect the woods, is promoted to a large extent by "outsiders." If they can be shown that the control of fires is worthwhile, they will no doubt be as staunch in support of fire control as they were in opposition.

Figure 7.--Forest or range land? Many acres of land in a condition similar to this are burned in Missouri each year. The trees are mostly defective and of non-commercial species. The forage production is low. Periodic burning prevents any new forest stands from developing but does not eliminate sprouts (which is necessary if forage production is to be materially increased).

STATUS OF FIRE CONTROL

The first organized attempt to prevent and suppress fires in Missouri forests was undertaken by the State during the 1920's. The size and complexity of the job were shown by the fact that the program was given up in the belief that success would be impossible. A second attempt was started in 1933, and although slow and discouraging in the beginning, it is here to stay.

The Forest Service, with the help of the Civilian Conservation Corps, started the second fire-control program in conjunction with the establishment of the first National Forest Purchase Units in Missouri. Their efforts were concentrated on the recently purchased National Forest land and intermingled private land. In 1938 the Missouri Conservation Commission was established. Its Division of Forestry was charged with responsibility for forest fire control and shortly established the State fire-control organization which is now carrying out a difficult job on state and private land.

The area under organized protection from fire in Missouri has increased rather steadily and now amounts to about 11 million acres (figs. 8 and 9). A few private timber operators provide some additional protection for their holdings. There are still more than a million acres in need of intensive protection, and about 3 million acres that need at least extensive protection. The unprotected area will be brought under State protection as rapidly as funds and personnel permit.

Much progress has been made in fire control within the protection districts. The most significant accomplishment has been to reduce the annual area burned per million acres protected in spite of increasing the area protected. It is estimated that 30 percent of the now-protected area burned each year before protection was started; this has now been reduced to less than 1 percent on many areas.

A great deal of effort has been made in fire prevention. Education has been stressed. Each district has carried on a program: school children have been visited, meetings attended, radio and television programs and movies presented, in addition to posters and exhibits being used. Probably in this area the most effective prevention method is personal contact between forest officer and resident. The work of the Agricultural Extension Service and of various cattle breeders has been helpful indirectly. The work of fostering better farm practices is certain to promote fire prevention. Farm Foresters are giving much needed help to timberland owners. Law enforcement and fire investigation have been effective in many cases and increased effort is being given to this activity.

The Missouri Conservation Commission, the U.S. Forest Service, and some private owners have made much progress in building physical improvements used in fire control, in the techniques of fire fighting, and in developing and adapting equipment for fire suppression. Four-wheel-drive jeeps are widely used for transportation. The trusted broom-rake is giving ground to tractor-plow units where formerly heavy machines were believed inoperable. Effective networks of lookout towers cover the protection districts and the use of aircraft in detection as well as in the supervision of fire control is proving successful. Communication systems, especially radio networks, have been established and improved. Training personnel in the use of equipment, objectives, safety, and techniques of fire fighting is a standard part of the fire-control program.

Figure 8.--Area protected from fire in Missouri.

In spite of the progress that has been made to date, there is still a long uphill job to be done to make forest land safe from fire. If the job is to be successful, present protection activities will have to be intensified and extended and research work will have to be speeded up to solve the many problems that are obstacles to the success of the program.

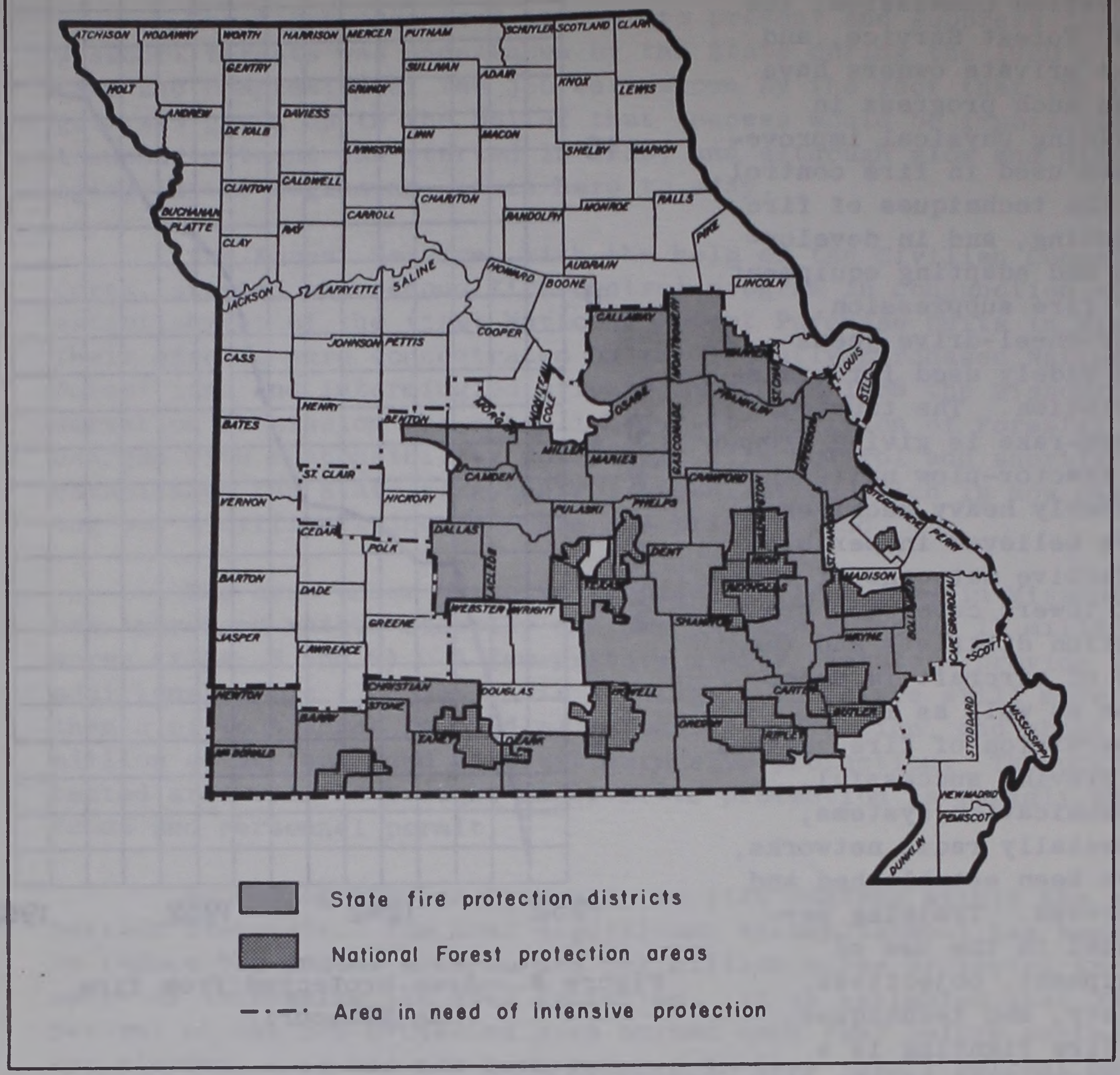

Figure 9.--Areas protected by the Missouri Conservation Commission and the U.S. Forest Service in Missouri.

MAJOR FOREST AND RANGE FIRE-CONTROL PROBLEMS

Burning of forest and range land leads to many diverse problems. There is, therefore, a need to survey all the problems, to evaluate them as to their relative importance, and to determine their priority in a research program. The program must provide for efficient use of present research manpower and facilities and also serve as a framework for future work so that the program may make its greatest contribution to fire control and to better land use.

The problems associated with fire are presented and discussed under the following major headings: (1) Fire Prevention, (2) Effects of Fire, (3) Fire Behavior, (4) Fire-Danger Rating, (5) Fire-Control Planning, (6) Fire Suppression, and (7) Uses of Fire. These are not entirely clear-cut or self-contained subdivisions. Many of the problems are so interrelated that none should be considered independently.

A list of major problems dealing with each topic is given in the Appendix (pages 48-53). Each problem is given a rating of relative overall importance. Indication is made of problems on which work is in progress and on which work is expected to be started in the near future.

Since these are major problems and are not broken down into much detail, most of them have high or very high importance ratings. In considering importance, it is easy to confuse expediency, facilities, personnel, availability of funds, and the immediate contribution that research can make with actual importance. An attempt has been made to rate importance on the basis of the actual relationship the problem has to fire control in this region. However, all the above factors were considered when selecting problems to be included in the research program.

FIRE PREVENTION

The immediate objective of fire prevention is to reduce the number of fires. Since there are currently 2 to 4 thousand reportable fires and an estimated 2.5 to 4 thousand nonreportable fires in the State each year, and since 99 percent of these fires are man-caused, there can be no question of the need for fire-prevention activities in Missouri. Fire prevention has more potential value for reducing area burned, saving expenditures, and building up the value and importance of forest land than any other single activity. Success in fire prevention has a high reward, but because of the ingrained habits and beliefs of the people, it is one of the most difficult fire-control tasks to accomplish.

Two Types of Prevention Problems

Fire prevention in Missouri must be aimed at two distinctly different problems. One problem is concerned with preventing fires on State, National Forest, and privately owned land managed for tree crops. The objective here is to protect the investment in forest site and growing stock. It is rare for fires to be authorized on such land and hence nearly every fire on this land is a result of carelessness or incendiarism.

The other problem is concerned with the prevention of fires on forest land not now dedicated to tree crops. The objective here is to improve and rehabilitate such forests. Fire prevention is aimed at people, landowners in particular, who do not presently attempt forestry and who, in fact, may earnestly wish to be rid of trees. Fire prevention is directed more specifically toward those owners of forests whose land is best suited to tree crops but who want to use the land for other purposes. Fire prevention and control are needed on this land because the growth of forest industries, which hold much economic promise for this region, will need the product of this land (which may amount to more than half the total forest land of the region) and because present uses are wasteful of both land and forest resources. This is a difficult idea to promote since a small ownership of presently low-quality forest is not a very strong inducement to practice forestry.

On this land fires are common; they are usually set intentionally and for a purpose. These fires are not incendiary as a rule for they are usually set on land owned by the burner. Though they may spread to land of another, the setting is not necessarily malicious.

Within the protection districts there may be as high as three fires on private land on which no action was taken, and hence do not appear in the record, to one fire on which action was taken and is included in the record. Thus the total amount of burning and the total effect on forest land productivity can only be approximated.

Since the two problems are so different, different methods are clearly required in fire prevention. In the one case, enforcement is a definite and positive tool; in the other the effect of enforcement may be hard to predict. Time, education, demonstration, changing economic conditions, and research may bring lasting reduction in fires. Indirect fire-prevention methods may be the most effective. The ground must be prepared to interest landowners in tree crops while eliminating the need of forest land for other purposes. In general, fire-prevention effort must be tailored to fit the specific problem or person at hand.

Incendiary Fires - Most Numerous

About 99 percent of the forest fires are man-caused and should be preventable. During the 10 years beginning in 1950, less than 1 percent of all the reported fires in Missouri were caused by lightning. Railroads, lumbering, and campers caused only 4 percent. These last three causes can normally be attributed to carelessness or mechanical failures. The remaining causes--debris burning, smoking, incendiary, and miscellaneous--accounted for more than 95 percent of all the 32,857 fires. More than one-third were classified incendiary. Although causes of these fires may range from carelessness to maliciousness, underlying most of them is a desire on the part of someone to burn, or general lack of concern if fires occur.

Because it is hard to accurately classify fires by general cause and because many people wish to burn the woods, classification by cause often loses significance. The general causes of fires are only symptoms of the more fundamental attitudes towards forest land. There is too little appreciation of the value of forest land as such; too much inefficient use of land; too little regard for the property rights of others; and too little opinion in favor of fire control. If rural Ozark people were to consider forest and range burning as a loss to themselves and their community--if they did not want to burn--there would be little fire prevention left to do.

Fire Control Involves Changing Ideas of Land Use

In this region, forestry and conservation represent new and somewhat radical ideas introduced within the past 30 years. Ideas that, because they are not well understood by the residents, seem to threaten their practices, customs, and habits.

Forestry aims essentially at good management of forest land but is closely allied with good use of all land. To get the best use of a great part of both the farm and forest land in Missouri requires much human adjustment. Such adjustments are accomplished through leadership or changing economics; they can rarely be forced or bought. For many people the necessary adjustments are complicated, even involving changes in farm operations, and they take place slowly.

Forest fire prevention is not an end in itself. It is important to good land use because good forest management and indiscriminate burning of the woods are incompatible. Foresters and conservationists should be for good land use--not simply against burning. A positive approach may be more difficult but it may also be more productive.

Stripped of all its perplexing details, the basic problem in fire prevention is: How can better use of land be accomplished? The number of fires in Missouri can be thought of as an inverse index of the quality of land use and management. It seems an inescapable conclusion that research leading to improved use of land and better practices will benefit fire control and further fire prevention. There remains, however, a task of proving such uses by education, demonstration, and promotion. How to accomplish this is itself a problem for research.

Laws and Enforcement Fill an Important Gap

Education, demonstration, and promotion are mainstays in any fire-prevention program. These are not enough, however, because certain individuals must be restrained by law from imposing their own willful acts upon the community. There is a definite place for good legislation with coincident enforcement in support of fire prevention.

The fire laws of Missouri are the best that could be obtained politically. They are not as complete as in many states, but they may have gone as far as practicable in the early stages of fire control. Lack of a burning permit requirement is one of the main differences from many state laws. Legislation and enforcement of laws without public support is usually doomed to failure. With public support they are a potent means of accomplishing fire prevention. Public support, especially in the forested areas, has developed slowly in this region. This is true of the courts as well as of the public. Enforcement has been difficult for it is not only hard to catch violators but hard to get convictions. However, efficient, well-timed enforcement has been and will continue to be a potent fire-prevention tool.

Legislation and law enforcement are not problems on which research is urgently needed, though it would be helpful to evaluate the effect of these devices upon fire occurrence. Administratively, however, they need careful study, and in time will no doubt be strengthened.

Research Priority

(See table 1, page 48)

Since forest fire prevention has such a strategic role in reducing fire-control costs and damages, research leading toward more effective forest fire prevention has very great importance.

Although there are few studies that can be said to be strictly fire-prevention research, there are many that can provide basic tools for doing effective forest fire prevention. These studies are widely distributed among many fields. Research in educational procedures and methods, land use, field and pasture crops, range and livestock management, forest and wildlife management, wood utilization, economics, psychology, and sociology all have phases directly applicable to the fire-prevention problem in Missouri. In the field of fire research itself, one of the most important needs is for fire effects information that can be used directly in fire prevention (see Fire Effects, page 22). Accurate fire-danger predictions and effective fire suppression are also tools in fire prevention (see Fire-Danger Rating, page 35).

Research in these fields is applicable to fire prevention because in order to get better use of land, sound practical land-use systems must be defined; better ways and means to sell ideas need to be found and used; effects of fires must be known; and the end result, good land management, must be made attractive and practical. Thus, it will often be necessary to solve grazing or sociological problems, for example, in order to prevent fire. It is not only necessary to find out what the people need but how to get them to want what they need.

In order for fire research to contribute to this important field, a realistic framework for operating is outlined. Fire research personnel should (1) keep informed of research in other fields that can be applied to forest fire prevention, (2) explore all local fire research results for leads to forest fire prevention, (3) present current research results applicable to forest fire prevention in attractive and useful form, (4) encourage and assist in research in other fields which is needed for forest fire prevention, and (5) conduct research on problems within the field of fire control applicable to forest fire prevention.

Fire research personnel can participate effectively in these five types of assignments. Although many applicable studies are outside the range of fire research, the fire research project personnel can serve as a clearinghouse for information and also promote needed studies in other fields, participating in the studies when and where possible.

Of the problems listed in table 1, page 48, problems 2 and
are aimed at seeking remedies to the ailing land-use situation. They are rather fundamental in nature. Such facts are urgently needed to strengthen the education program.

Problems 1 and 3 are related and deal with the problem of how to use the knowledge we have or can obtain to present convincing arguments so that they will be accepted and respected. Pursuit of studies on problem 1 will require qualified specialists. Some such work is being done by other groups and will be used to the fullest extent possible.

Problem 4 describes the measurement of prevention accomplishment and methods. Although dramatic results need no measure, often the effective result is obscured by severe burning conditions. Administrators need to discriminate between real and false interpretations of the result of their efforts and this problem deserves a part in the program.

Problem 6 is of lesser importance now since people more than fuels influence fire occurrence; later on fuel reductions may be of greater importance and will need analysis and study.

EFFECTS OF FIRES

Burning forest and range land means different things to different people. Fire control is carried on to eliminate the consequences which are detrimental. Together the State and Forest Service currently spend over $900,000 a year in Missouri for fire control. On the other hand, people in Missouri have been burning the woods for many years because they considered the results to be beneficial and, in some cases, necessary.

This paradox is a result of imperfect knowledge of the immediate and long-range effects of fires and lack of sound, long-range, land-use plans. The conflict is likely to continue until better fire-effects data are obtained and land-use capabilities are better known and utilized. The problem for research is to define and measure the effects of fire, good or bad.

Effects of fire may be direct or indirect. The direct effects of fire are caused either by the chemical reaction (combustion) or by the heat that is given off during the process. Living things, plant or animal, may be killed or otherwise affected by the heat, and both living and dead materials can be reduced by the chemical reaction to ash and various gases. All other results are indirect, evolving from a chain of events set off by killing or consuming organic material. The direct effects are immediate and mostly tangible while the indirect effects may be delayed and are sometimes intangible. The results of burning may be variable because of differences in fire intensity, size of fire, season of burning, kind and location of fuel, and kinds of things affected.

There are many uses for fire-effects information. Such information helps in setting better fire-control objectives and supports fire-prevention education. It helps also in forest, range, and wildlife management. Once the physical effects of burning are known, it is relatively simple to use this information in fire prevention, land management, or economic analysis. The value of property and its susceptibility to damage affect the intensity of protection which is reflected in cost of protection and the economy of the community.

The effects of fires will vary with the behavior of the fire. This problem persists throughout all studies in fire effects. Since this variation is so important to the interpretation of results, some measure of fire behavior is required in order to describe the conditions of the fire and to predict future effects under similar conditions. Techniques and methods to measure fire behavior are not well developed and are urgently needed for fire behavior studies as well as for fire effects and uses studies (see Fire Behavior, page 30).

In view of the variety of effects that may result from burning, the problems involved are discussed under the following subdivisions: The effect on (1) vegetation and forest floor, (2) soils and water relationships, (3) microclimate, (4) recreation and wildlife, and (5) management of the resource and stability of communities.

Vegetation and Forest Floor

The effects of fire on vegetation and the forest floor are usually the most obvious and immediate of all the effects of fire. Most fires kill the tops of small plants; some fires kill the tops of larger plants, including mature trees. Any fire is likely to scar the boles of trees, allowing decay organisms and insects to enter causing loss or degrade of wood products or death of the tree (fig. 10). All fires destroy part or all of the forest floor.

Specific information on the physical effects of fires on the vegetation and forest floor is needed in all phases of resource management. With fires of various intensities, how much mortality and injury will be sustained? How can mortality and loss be predicted soon after a fire and how soon will they be evident? How much will the quality or vigor of the tree be affected? How will the cover type change after the fire? How will different species respond to the fire? Accurate information on these points is not now available but is needed.

Figure 10.--Fire scar on a black oak tree. Two to three years after a fire the bark begins to sluff off where the heat killed the cambium. Insects and wood-rotting fungi enter the wound and destroy wood in the most valuable log of the tree. Ten years after the fire this wound has still not healed.

One of the first objectives of forest and range management is to maintain an adequate stocking of desirable plants that will grow at a rapid rate. Fires may influence the origin, species, and age composition of stands. It is possible that repeated burning may also change the soil and moisture conditions and otherwise alter the site so that its adaptability for various species and its productive capacity are impaired. What has been the effect of past periodic burning on the kind and condition of forest trees in the Missouri Ozarks? To what extent are the present low-grade forests and ranges a result of burning? These are ecological problems as well as fire problems and bear significantly upon the practices required to successfully manage forests and ranges. Since fire is only one of the ecological factors at work, it is important to isolate its effects. This information is needed to help determine the intensity of fire control needed, to provide facts for fire prevention, and for the management of forests.

Soil and Water Relationships

The Ozark soils are chemically and physically poor with much more active erosion than is evident to the casual observer. Good agriculture and forestry should prevent deterioration of soils; in fact, soil usually must be improved if land is to be fully productive. Forest humus is derived from the leaf litter, twigs, stems, and roots of the trees, brush, and herbs that grow and die in the woods. When this material is periodically burned, it is lost as humus to the soil and the ash, including mineral nutrients, may be washed away (fig. 11).

Soil is not only mineral and organic material; it also includes micro-organisms and small animals. Some of these organisms change organic materials into available plant nutrients. This living community is necessary to the existence of the higher forms of both plants and animals. These constituents maintain or improve

Figure 11.--Forest fires destroy the forest floor. When the forest litter is periodically burned it is lost as humus to the soil. The ash, including most of the mineral nutrients in the litter, and the topsoil may be washed away. Water retention is reduced and runoff increased. These results of burning all act to deteriorate the site quality. (Photo courtesy of the Missouri Conservation Commission.)

the fertility and tilth of the soil and its permeability and capacity to hold moisture. They help to reduce erosion and the leaching of plant nutrients. Changes in these conditions are not readily measured. They are indicated by the amount of runoff of water, the growth of plants, and changes in occurrence of species of plants and animals. Too little is known about how much the physical, chemical, and biological character of the soil is changed by burning or exactly what changes take place and how long it takes the soil to recover; yet these are important aspects of land use.

The role of forests and ranges in holding water for gradual release to streams and in holding the soil in place has been studied in many locations and much has been written on the subject. Locally, neither the quantitative nor the qualitative effects are well known. The value of water is more and more being appreciated. Soil moisture is a critical factor of plant growth and therefore the capacity of the soil to absorb and hold moisture is critical. A great deal needs to be learned about the role of burning in relation to soil moisture, stabilization of streambeds, streamflow, erosion, and runoff.

The Climate Near the Ground Surface

Climate varies with distance from the surface of the ground. Although macroclimate, based upon measurements taken 4.5 feet above the ground, receives most attention in describing the climate of an area, microclimate, based on the climate of small spaces, is of much importance to biologists. The extremes of the climate at the soil surface or 6 inches above the surface, for example, are often more severe than at 4.5 feet above the ground. This microclimate is greatly influenced by vegetation, color and texture of the soil, litter, aspect, slope, and moisture.

For example, after burning, the black surface and the increased exposure make the surface climate more severe. These changes may result in a drier site or in lethal temperatures for seedlings and soil micro-organisms. Fuels become flammable quicker and wind is stronger so that burning conditions are more severe and the period of flammability is longer. Information on the magnitude of microclimatic changes on a site following fire are of value in managing burned-over areas and are essential in rating fire danger.

Wildlife Habitat and Recreation

The forest is the habitat of many forms of wildlife and is used extensively by people for recreation. More than three-quarters of a million hunting and fishing permits are sold in Missouri in a year and thousands of people enjoy the forests for vacationing, hiking, picnicking and touring. Receipts from the sale of hunting and fishing permits help to support the activities of the Missouri Conservation Commission, and recreationists bring business to local merchants.

The value of the forest as wildlife habitat, the value of the wildlife itself, and the worth of the green forest as a place for recreation are intangibles. Terms and units need to be found to express the value of wildlife habitat and recreational worth of the forests. Such units are needed to determine losses when they occur. Even though it is difficult to set a dollar value on these forest uses, they are assets, and management practices that enhance them are desirable.

When the forest is burned, some animals are killed, wildlife habitat is altered, and the area is left unattractive for recreation. How does burning affect game food supplies and forest recreational uses? Can this effect be evaluated? What is the relation of size, intensity, frequency, and location of fire to significant changes in these values? How does burning affect wildlife population, health, and vigor?

A knowledge of the specific effects of fire, the requirements of wildlife, and choices of recreationists is basic to the solution of these problems. The task of managing areas for multiple use, including wildlife and recreation, can be done more easily and more intelligently when the effects of fire are more fully known.

The Management of the Forest and Range Resource and the Stability of Communities

Forest communities need a steady and reliable flow of wood products to maintain economic stability. This flow of raw material depends upon good management of the forest. However, even the best management cannot compensate for the lost time in regenerating fire-killed or damaged young trees and rebuilding site quality, nor can it substitute sound wood for defective wood resulting from fire injuries and mortality. These are losses to a community. They can be demonstrated in take-home pay and in returns on investments.

They will surely affect the quality of workmen who will live in a community and they very significantly effect the markets for products and multiply the forest manager's problems.

Fire often causes increases in the amount of hazardous fuels, thereby increasing the risk of loss in adjacent forest areas and further losses on already burned areas. Management must calculate the loss that can be permitted from fires without defeating the plan of management and must also provide a level of protection sufficient to insure against greater loss. Protection against fire is necessary to warrant private investment in forest growing stock. Failing such protection the investor will normally liquidate his investment with disastrous results to the community.

Range burning has been practiced in Missouri for many years. Wild ranges are generally forested or partially forested and are generally in poor condition. The effects of burning are mixed with the effects of overgrazing so that the role of fire as a tool in range use is not clear. There is reason to believe that burning and overgrazing in combination increase the rate of range deterioration. Because livestock provide about three-fourths of farm income, the effects of fires on wild ranges have an economic impact on Ozark communities.

Communities are influenced by all the effects of fires, but how these specific effects, such as effects on forest and range vegetation or watershed, individually affect the community may be vague to the people. When the collective results of burning can be shown, the effects on the economy of the community may be better understood by them. The problem in research is to identify the specific fire effects and evaluate them in terms of community loss and land management requirements.

Research Priority

(See table 2, page 49)

Among the various effects of fires, the effects on vegetation and forest floor occur first and are important guides to subsequent direct or indirect effects. Effects on vegetation and forest floor involve the harvestable product of the land and will influence the value, use, and further protection of the site. These effects, therefore, are very important and undoubtedly should receive first study (table 2, problem 1).

What happens next to the land and vegetation sequence is mostly a consequence of the vegetational change due to the fire. Effects of fires on soil quality may have a strong bearing upon

subsequent land use and consequently are also problems of very high importance (table 2, problems 2 and 3).

The effect of fire on the microclimate (table 2, problem 5) is an indirect result of vegetation and forest floor modification. These changes help to explain the subsequent development of plants and fuels, but are of lesser importance than the primary effects that cause them. These effects are not scheduled for study except in connection with fuel moisture and wind studies related to fire behavior and fire-danger rating.

Effects on wildlife and recreation (table 2, problem 6) are a by-product of vegetation and site changes also and are secondary to them. The solution to this problem first depends upon solutions to problems 1, 2, and 3. Although wildlife and recreation values are close to the public and to conservation programs in general, they are not fundamentally important for fire research. Likewise, the manner in which fires affect forest management and communities is of great importance to the community affected. Attack on the problems is subject to applications of results of problems 1, 2, 3, 5, and 6. These problems are secondary but still of high importance.

As isolated facts the solutions to problems 1, 2, 3, 5, 6, and 7 have value and interest, but to utilize them to the fullest extent these effects must be evaluated (table 2, problem 4).

Research can contribute greatly to this fund of needed information. Very little specific information is available and immediate guides are needed for damage appraisal. So until better information is available, approximations of damages must be made by administrators from the meager current knowledge. Corrections should be made periodically from the findings of research, These studies should have rather wide application within the central states and, therefore, have greater importance.

To carry out the full line of studies will require assistance from specialists in the fire laboratories as well as in other fields such as plant physiology, soils, forest influences, wildlife management, watershed management, and economics. Primary responsibility rests with fire research personnel for coordination of work to focus the results more directly on the problems of fire control.

FIRE BEHAVIOR

The study of fire behavior is the very essence of fire research. Given certain conditions of fuel, temperature, fuel moisture, and draft, combustion will take place. The resulting fire acts precisely according to physical and chemical rules, many of which are imperfectly known or completely unknown, and any or all conditions may change during the course of a single fire. The actions of a fire, e.g., ignition, rate of fuel consumption, rate of spread, crowning, spotting, whirling, sweeping, surging, fingering, and perhaps some other phenomena, are called more or less collectively "fire behavior".

The general purpose of fire-behavior study is to learn how to predict the behavior of fire. The job breaks down into four parts: (1) To learn the basic theories and natural laws related to chemical, physical, and kinetic aspects of free-burning fires, (2) to measure the characteristics of fires that create problems of prevention and control and result in varying effects, (3) to measure the wild-land fuel and environmental factors affecting fire behavior, and (4) to correlate the effects of fuel and environment on fire behavior.

In all these there is a scarcity of exact knowledge and a great need for both basic and applied research. But fire fighting agencies need information currently, so in spite of the lack of fundamental data, approximations must often be made from the empirical data at hand. These approximations must be corrected and refined as research progresses.

In the Central States little has been accomplished in fire-behavior research although the large numbers of fires have given many men a practical knowledge of normal fire behavior. When conditions are severe or change rapidly, fire fighters are frequently unable to recognize the change and may misinterpret fire behavior with consequent loss in area burned and lives endangered.

Basic Theories and Natural Laws Relating to Chemical, Physical, and Kinetic Aspects of Free-Burning Fires

The process of unconfined combustion is a poorly understood phenomena in spite of the thousands of years man has used fire. If a better basic knowledge of combustion processes existed, the job of selecting the information needed to measure fire danger would be simplified. Many problems in fundamental research need much more attention. Specialized technicians and laboratory facilities are required for this type of research. So fundamental research of this nature is likely to be concentrated at one station

or laboratory. Application of the findings of fire laboratories will be the chief function of this project.

Measurement of the Characteristics of Fires that Create Problems of Prevention and Control and Result in Varying Effects

"Unless you can measure what you are talking about and express it in numbers you know very little about it." This quotation from Lord Kelvin applies nicely to fire behavior. In fire control we have very inadequate means for describing fires. Terms of a general nature such as low or high intensity, creeping, running, blowup, rate of spread, spotting, and crowning, are some of the terms used to describe fires. Some, such as rate of spread, are empirical measures. But, what does low or high intensity mean in terms of measurable quantities, and how could such a quantity be measured in the field? Our useful knowledge of fire and fire behavior will be greatly advanced when better means are found to describe fires.

The existence of such means of measurement would make possible much more accurate correlations with the various factors affecting fire behavior, and better application to the problems of fire effects and danger rating.

Basic measurement studies of this kind will not be conducted by the Central States Station. However, it may be a long time before precise means to measure and describe wildfires become available so there remains the problem of improving on empirical methods which will provide better practical applications.

Measuring Wild-Land Fuel and Environmental Factors Affecting Fire Behavior

The known basic factors affecting fire behavior can be roughly divided into two groups (1) fuel factors and (2) environmental factors. The fuel factors include such things as volume, moisture capacity and content, arrangement, size, shape, position, chemical composition, heat value, compactness, conductivity, and ratio of green to dead fuels. Environmental factors include one group of relatively unchanging factors, such as topography, slope, exposure, and geographic location. A second group includes factors which change hourly, daily, or seasonally: Precipitation, humidity, evaporation, condensation, temperature, and general atmospheric conditions including the horizontal and vertical distribution of temperature and moisture.

Individual particles of fuel such as a twig or leaf can be rather readily described, but most fuelbeds are complex consisting of different kinds of particles having many different properties. Moreover, fuelbeds may vary greatly in small distances, so the problem of defining fuelbeds is complex.

The gross effect of many of the fuel and environmental characteristics on fire behavior is fairly well known though the precise effect or the reason may not be thoroughly understood. It is possible that other characteristics may yet be found to be important.

Specifically we need to find means and techniques to measure the variable fuel and environmental factors and to find the critical range of each. For example, it is important to determine how much and what kinds of fuel are to be found in different stand types. This can lead to evaluation of fuels and fuel associations which is needed information in fire-danger rating.

Since fuels are not static over a period of years, in planning for fire control not only the present fuel but also the expected fuel changes in succeeding years must be considered. This necessitates determining the character and rate of accumulation of new fuel as well as the rate at which existing fuels, such as litter, slash, dead standing timber, and windfalls disintegrate. In this region periodic burning has been so widespread that hardly any woodland can be found with a long, undisturbed forest floor. Fuels may change significantly under protection and management, and the change will be important to fire control.

Measuring moisture content or temperature of a specific fuel sample is not difficult. However, the problem is to correlate sample fuel moisture, such as might be measured at a danger rating station, with actual fuel moisture in similar or different fuels somewhere else. Suitable materials and instruments must be selected and properly located to obtain accurate data on fuel moisture at the central station and to make correlations with fuel moisture existing at the places where fires are likely to occur.

Because moisture content of fuels varies during the day, any one measurement soon becomes obsolete. Extending the period for which moisture conditions can be predicted would greatly increase the usefulness of the information and permit better planning. Efforts to extend the prediction periods should be given serious study and correlated with weather forecasts, short and long period precipitation records, ground water levels, streamflow and such other indices as may prove of value.

Air movements are of vital concern to fire behavior. Oxygen is supplied for the combustion process and heat and sparks are carried to unburned fuels by drafts. Rate of fire spread is related to windspeed. Windspeed is frequently the difference between an easy fire to handle and a blowup. In order to predict the effect of wind on fire behavior, studies must be made to find out how windspeed and direction are affected by atmospheric conditions, topography, cover, and by fires of different intensities and sizes. Proper wind-measuring-instrument exposures must be determined and methods devised to estimate the winds at various locations based on the standard exposure data.

The Effects of Fuel and Environment on Fire Behavior

Neither measuring the fuel and environmental factors nor measuring something about a fire alone will provide all the information that is needed for fire control. The two must be related--cause and effect--so that the influencing factors can be evaluated in terms of fire behavior. These relationships, when established, form a basis to predict fire ignition and behavior and evaluate fire danger, and become a tool in planning fire-suppression forces and tactics.

Wildfire behavior is influenced by the many fuel and environmental factors. It is necessary to determine how these factors, individually and in various combinations, affect ignition and fire behavior.

These factors vary greatly from time to time and place to place. Some of them, moisture for example, are critical in that high moisture content prevents fires from starting or spreading. Others, such as wind velocity and slope, have wide ranges but their extremes usually do not prohibit fires. Any factor may vary independently, either in time or from place to place. Thus the most useful correlations are multiple correlations which indicate the effect of the several variables at any one time.

Research Priority

(See table 3, page 50)

The study of fire behavior and its causes is of concern in fire control for it is basic to so many fire-control functions. Some of the objectives of such studies are:

a. To learn how to predict the action of a fire.

b. To serve as a basis for planning suppression strategy and action.

c. To help in setting up realistic objectives of fire control.

d. To provide a basis for evaluating fire effects.

e. To permit greater safety in fire suppression.

f. To estimate the difficulty and hazards of fire suppression.

g. To permit estimation of fire danger.

h. To help plan current fire-prevention activities.

i. To help in planning prescribed burning.

There is a logical sequence in fire-behavior study from discovery of natural laws and theories relating to the combustion process to measuring and interpreting the factors which influence the behavior of fires. Since many of the natural laws are not understood and not yet stated by formula it is necessary in many instances to work in an empirical manner from effect to cause in order to obtain reasonably accurate results by which fire-control activities can be guided. In the meantime, as more accurate methods and data become available, they can be put to immediate use.

Of the problems in table 3, numbers 1 and 2 in particular and some aspects of numbers 5, 7, and 8 are problems that can best be worked on at the regional fire laboratories. These are very important problems for all advances in the basic knowledge of fire should go far towards the understanding of many other problems.

Problems 3 and 4 dealing with local fuels; 5 and 9 dealing with fuel moisture; and 6, 10, and 11 dealing with local wind and weather are local problems of much importance. Much of the information that may be derived from the study of these problems is needed to make use of the basic studies and make application to local problems.

Problem number 8, the correlation of factors influencing fire behavior with the behavior of fires in the Missouri Ozarks, is perhaps the most important single problem in the program. Its solution is contingent upon solutions to a great many other problems. Piece by piece the parts of this complex problem will fall into place. Thus while no over-all attack is planned, as other studies yield applicable results progress should be made on correlations that can be used to predict fire behavior with increased accuracy.

FIRE-DANGER RATING

By definition, Fire Danger is: "The resultant of both constant and variable factors which affect the inception, spread, and difficulty of control of fires and the damage they cause" (4). Fire-Danger Rating is: "A fire-control management system that integrates the effects of selected, fire-danger factors into one or more qualitative or numerical indices of current protection needs" (4). Fire-danger ratings should indicate answers to several questions: What is the probability of fires starting? What is the probable behavior of fires? What forces will be required to suppress fires? What is the probable loss or damage to be expected? Fire-danger ratings provide guides to appropriate action--they are not substitutes for judgment.

Fire-control agencies in the central states use a device known as the Fire Danger Meter for Use in the Central States. This device is a burning-index meter rather than a danger meter because its ratings are based upon selected variable factors only. It provides an estimate of the relative importance of wind, season, and moisture as they affect ignition and fire behavior. It is an important device in fire-control planning in this region and every effort to test and improve its reliability and to incorporate other factors leading towards a comprehensive rating of fire danger should be made.

In the central states, the value of fire-danger rating may increase as time goes by. On some areas there is enough fire business alone now to provide nearly full-time work for several men. But as fires decrease, experience in fire control will be lost and more reliance must be put on guides to appropriate action which fire-danger rating can help to supply. As a result, the ratings will become of even greater importance in the planning of fire-control activities.

Fire-danger rating needs to be correlated throughout the country. Some of the fundamental work can best be done in central laboratories. There are many phases of the problem that must be worked out locally on the ground, however.

In the task of developing better fire-danger ratings, the chief function of research is to measure and evaluate the effects of each variable on fire danger and to combine the separate results into a rating that will indicate the degree of fire danger and the appropriate action. The interrelation of factors makes this an intricate problem.

Probability of Fires Starting

The probability of fire is regulated by the number and effectiveness of causative agents and by the flammability of fuel. The number and severity of fires occurring within a protection area determines, to a large extent, the fire-control-job load. Fire danger is nil when the probability of fire is nil as, for example, when there are causative agents present but the ground is covered with snow, or when there are abundant fuels in condition to burn but there are no causative agents present. However, the probability of fire in the Missouri Ozarks is usually greater than zero. The important problem is to determine the current probability of fire occurrence and how it varies with time and place.

Causes

In the Ozarks, where almost all fires are man-caused, fire occurrence is not so much governed by the random existence of probable causes as it is by the attitudes and customs of the residents. Since the reasons for burning vary, fires may occur under almost any conditions. Although fires occur throughout the year, by far the heaviest concentration is in March and April, the customary time for range and debris burning.

Because there is no burning-permit law in Missouri, the fire-control agencies have no advance knowledge of or control over the setting of fires. A decision as to whether action has to be taken on a fire or not has to be made on each smoke or glow that is seen within the protection boundary. Because there are so many intentional fires on private land there are many false-alarm fires that add to fire-control costs. It is interesting to watch an experienced fire dispatcher pinpointing numerous fires on his map, cataloging them as to known-control burns, no action required; doubtful-control burns to be checked on the ground; and wild fires, to be suppressed. Much of his value to the organization lies in making correct decisions based on his knowledge of the people, the country, the burning conditions, and the appearance of smoke as described by the lookout. The dispatcher is only a figurehead without firefighters, however, so he must also have estimated the probable job load and have firefighters on tap. A better basis for estimating probable fire occurrence is needed. How is fire occurrence correlated with weather, season, day of week, time of day, special events, and other factors?

Flammability of Fuels

The conditions that affect fuel flammability also affect fire behavior. The possibility of a fire being started by a brand varies inversely with the moisture content of fuel, within limits,

And varies with the kind, shape, size, and position of fuel and to some extent the wind velocity. The basic problem is to devise methods to estimate the probability of fire at a given prevalence of fire-starting agencies and a given kind and condition of fuel. The estimate may also have a use in establishing trends in occurrence from year to year and thus will serve as a means of judging accomplishments in fire prevention.

Probable Behavior of Fires

Fire behavior is related to many different fire problems (see Fire Behavior, page 30). It is one of the elements of fire danger. Many of the problems listed under fire behavior (table 3) must be solved before accurate danger rating is possible. A primary objective of fire-behavior studies is to determine the relation of the several variable fire-danger factors to ignition, character, and intensity of fires. In rating fire danger the objective is to adapt these relationships to predict the behavior of fires. It is important to recognize unusual conditions that may result in blowup fires as well as to indicate the more common situations. The effects of prolonged drought and unstable atmospheric conditions are particularly in need of study.

Probable Resistance to Suppression of Fires

Forest and range fires occur under a great diversity of conditions. It is to be expected, therefore, that the difficulty of fire suppression will vary greatly from place to place and time to time.

Resistance to suppression is a factor of fire danger, since the fires that are more difficult to control require greater suppression effort and have greater possibilities for escaping and doing damage. Resistance to suppression is a measure of the effort required to control the spread and intensity of the fire. This is the end product of the fire-danger rating: To indicate the appropriate control action.

Resistance to suppression of fire is of two kinds: (1) The resistance of the dynamic fire itself to extinguishment, and (2) the resistance offered by the site to fire-control line building (generally called "resistance to control"). The aggressiveness of a fire and its resistance to suppression are indicated by its intensity and rate and means of spreading. The resistance of the site to line building is governed by topography; rockiness; kind and moisture content of soil; amount, kind, size, shape, and distribution of fuel; and density, size, and toughness of the vegetation. It also depends upon the method of control, equipment and tactics used, and the skill and efficiency of the firefighting personnel.

There is no completely satisfactory means to measure or express either type of resistance at present.

Probability of Loss or Damage

The danger of fire is more than the probability of occurrence the behavior of fire, and the resistance to control. The very term "fire danger" implies that uncontrolled fire can do damage. The extent of the damage that may be done will depend, in part, upon the amount and value of damageable material and the future loss to stands and site.

Present and future values should, in large measure, guide the intensity of protection. Truly efficient fire-control organization would vary the intensity of protection with value of each area. However, this would be very difficult, particularly in a region like the Missouri Ozarks where the values may vary widely from acre to acre. Although one tract may be comparatively worthless, it may lie adjacent to another tract that has high value. Fire control is not so precise that small adjacent tracts of different value can be given different treatment. It is necessary over much of the region, therefore, to suppress fires on low-value land as vigorously as on high-value land simply to prevent spread into more valuable areas.

Two things must be done in order to adjust protection to value: First, determine the values to be protected from fire, such as forest growing stock, forage, soil, recreational use, wildlife, and watershed; second, determine the damage fire can do to these values. The objectives of fire control and the methods of fire fighting need to be adjusted so that the losses will be within acceptable limits.

Research Priority

(See table 4, page 51)

Since many fires will continue to occur, men must continue to organize suppression forces. One of the most useful planning guides that can probably be devised is a system for rating fire danger. Moreover, when fires are rare, a knowledge of fire potential is still valuable. Danger-rating systems are far from perfect, so continued study of the problems of fire-danger rating is needed.

A danger-rating system is developed from results of many different studies combined to show the effect of variable factors on fire danger. Thus, in the logical progression of fire research, fire-danger-rating systems would be almost the final product.

However, administrators have needed such devices so urgently that already empirical methods to provide them have gone further than basic studies. This is acceptable if provision is made to pursue the basic studies and if the empirical guides are corrected and improved as better information becomes available. There is much room for improvement nationally as well as locally in fire-danger rating. Many workers must pool their resources in the task, and the local effort must depend heavily on other workers for much basic knowledge while striving to improve the local rating system.

It is important that a plan be developed soon to outline the most practical long-range objectives for a fire-danger-rating system for this region (table 4, problem 1). Such a plan would help to coordinate work on the various parts of the problem, thus eventually saving time and effort and should provide for current improvements in ratings without loss of continuity. Such a plan should also be coordinated with any nationwide efforts to standardize danger rating.

Except for problems 5 and 6, each of the other problems in the list states a specific segment of the general problem of fire-danger rating on which information is needed to give a sound basis for improving the current rating system. Each one must eventually be studied, though present appraisals assign some variation in importance to them.

Problems 5 and 6 need study because frequent testing of the danger-meter ratings must be made to detect flaws in the ratings as well as to furnish up-to-date evaluations of them. Testing other danger meters can also supply good leads for adopting or discarding various concepts in danger rating for local use.

FIRE-CONTROL PLANNING

Most of the problems discussed so far have had as an underlying objective more precise planning of fire-control activities. Planning is needed to keep losses from fire at an acceptable minimum consistent with the cost of doing the job. Even though fire prevention may reduce numbers of fires greatly, the threat of accidental fires requires that a well-trained suppression organization be available when there is fire danger.

The actual planning job is an administrative function but good management is not just happenstance. Sound planning and correct decisions are based on thorough knowledge of each part of the job that needs to be done. Regardless of the kind of plan, there is always a need for better methods and elimination of guesswork. Information and interpretation of information are needed to set realistic objectives and policies and to lay effective plans. Results of all fire studies are therefore brought into the field of planning.

Research in fire-control planning includes (1) the accumulation of fire research results and facts as a foundation for making plans, (2) developing concepts and methods for using information and adapting it to the planning procedure, and (3) testing and evaluating the results of planning.

Objectives of Fire Control

The objectives of fire control must be realistic yet purposeful. Too high an objective results in high costs; too low an objective results in large losses. In setting objectives, values protected, probable losses, and costs of protection should be considered. Short-term as well as long-term objectives need to be considered. Timber values alone on many protected areas at present probably do not justify the expense of protection. Without protection some of this land may never produce much income, but with protection it has a potential value. Thus the costs of protection sometimes are actually an investment in future capital rather than an operating expense since protection is a means to build the forest, range, water, or soil resource. This investment should eventually help to bring greater economic stability and better livelihood to the people. Thus a sound objective backed by appropriate action has a great impact on resource development and use.

The objectives, however, must be founded on solid information. Fire-effects information and accurate danger rating are two cornerstones in fixing an objective and implementing it. From this knowledge

administrators can more intelligently determine probable losses and determine the probable cost of protection and the acceptable minimum standards for protection.

Fire-Control Improvements

Protecting large areas from fires requires detection, communication, and roads as well as equipment, equipment maintenance facilities, storage, and headquarters buildings. In some instances, airfields and firebreaks must be built and water supplies developed. The objectives of fire control help to determine the quantity of these facilities needed, but behind the planning for them must be the knowledge of fuels, topography, climate, and present and potential values, which affect the behavior of fires or urgency of control. Detection, communications, transportation, and suppression forces must be in balance to permit getting a crew to a fire in any part of the district in sufficient time and strength to control the fire at reasonable size. This requires that rates of spread, difficulty of control, travel time, rates of suppression, communications, and locations of manpower be carefully analyzed and that equipment to meet special needs be developed.

In these activities, research can be helpful in the analysis of individual problems, stating concepts, testing, and in general bringing the scientific method to the planning procedure.

Weather Forecasts

Since danger ratings depend upon the current weather, they are not predictions of danger but merely indications of existing danger. Although it is of much value to have a current measure of fire danger, fire-control plans must be several hours ahead of action. Dependable weather forecasts provide the means by which fire-danger ratings may be projected into the next 6 to 48 hours. It is of particular importance to be forewarned of changes of weather conditions that may be impending within this period to permit better planning. Moreover, sudden changes may occur when the firefighting personnel are scattered and not easily reorganized.

There are many problems connected with weather forecasting for fire-control work. Most of these fall outside the province of fire research and are the responsibility of the Weather Bureau. Fire research should not be concerned with forecasting techniques. Fire research should, however, be concerned with the development of the techniques for using forecasts to predict fire danger. Aside from using the forecast itself, it is important to be alert to the needs of fire control so that forecast services can be expanded, where possible, to include new features of value in predicting danger rating. Much thought is now being given to the

atmospheric conditions that make blowup fires possible. When and if the situations that allow unusual fire behavior are sufficiently defined, it will become a task of the weather forecasters to attemp to forecast these conditions.

Training and Safety

The fire-control organization is made into an effective force only when each person knows what he is to do, how he is to do it, and how his job fits into the general organization. There is an ever-present need to train new and inexperienced personnel, to train older and more experienced men in new and more responsible jobs, and to improve skills in old jobs and procedures.

Firefighting is a hazardous occupation. Nearly every year one or more firefighters is killed and others injured in line of duty in the United States. In many cases more thorough training in methods and a better knowledge of fire behavior could have reduced the number of accidents. Much emphasis is and should continue to be placed on safety in firefighting.

As fire occurrence is reduced, the opportunities for on-the-job training are reduced and more off-the-job training is necessary With less opportunity to maintain proficiency through practice, the is danger of losing efficiency and allowing fire-control organizations to deteriorate. This situation is not prevalent in the Ozark but there is a constant need for off-the-job training for new men, for improving the technical knowledge of experienced men, for intro ducing new methods, and for preparing for new conditions.

Many of the results of studies dealing with danger factors can be used as training aids. All fire studies that lead to a better understanding of how to anticipate fire behavior will lead to greater safety in firefighting.

Research Priority

(See table 5, page 52)

Planning the fire-control activities is the final job short of suppression itself. Where fire control is an established under taking or where it is even just being organized, plans must be mad even if made up exclusively from estimations. Planning, however, is a continuous process. Fire plans are periodically reviewed and adjusted. Consequently, as better information becomes available it can be incorporated. This means that there is a ready market for research data but in most cases much depends upon other studie

for the basic information as raw material for the planning process. Administrators as well as researchers should keep in mind, however, that the planning process is a fertile field for defining problems for research.

The planning aspect of fire control is very important to administrators. The assignment of priority to problems (table 5) is a reflection of apparent current needs. Good use is being made of current knowledge; therefore, the needs are for new information. When this is available it must be adapted and assimilated. Thus, in the program for research, planning studies are somewhat opportunistic and no major work is planned for the near future.

FIRE SUPPRESSION

In spite of fire prevention and good intentions, fires are certain to occur. Through quick and adequate action, many of them can be held to small size. Suppression of large fires calls for a high degree of managerial skill. Where this skill cannot always be gained from experience on similar fires, it can be induced to some degree through a knowledge of fire behavior, methods of control, and good administrative procedures.

Many years of experience lie behind the present local methods and tactics of fighting fires. However, it is generally agreed that the nature of fuel and the resistance to suppression change with time after a burn. Fire behavior and resistance to control will be somewhat different as a result of a more mature forest floor. The need for prompt and adequate action will increase, more emphasis must be given to patrol and mop-up work, and new and improved methods and equipment for suppression may be needed. As the fuels change, firefighting techniques and tool development must also change.

Depriving a fire of fuel is the most extensively used control measure in the Ozarks. Men with broom rakes form the backbone of fire-suppression work and the "one-lick" method is the standard (fig. 12). Broom rakes are well suited to the job of clearing lines in light, leaf fuels. More expensive and oftentimes hard-to-get labor, greater accumulation of fuels, and the successful demonstrations of heavy equipment have caused interest to develop in power equipment for use in fire suppression. The techniques of using power equipment and the organization and function of operating and supporting crews need to be further tested and evaluated.

There is ample room in fire suppression for development of ideas, methods, and techniques. Even the most skilled technician

must, in most cases, fight fire at the places and times that the fire will permit. As yet technicians are unable to make direct attack on an intense fire as it rolls uphill or is crowning or rolling along on a flat. White no panacea may be forthcoming, it is conceivable that more positive means of fire suppression may yet be discovered.

Research Priority

(See table 6, page 53)

In this region weather conditions often create serious fire danger. The fuels are conducive to rapid spread of fire and hence large fires, but an extra period fire is very rare. Because of changes in fuels, suppression is becoming more difficult so there is opportunity for improvement in fire-suppression methods though it is not as serious a problem in fire control as many others.

Figure 12.--Men with broom rakes form the backbone of fire suppression work in the Missouri Ozarks and the "one-lick" method is the standard of crew organization. As the ground cover is allowed to develop under fire control, the broom rake becomes less effective and focuses interest in power methods.

USES OF FIRE

In the discussion of fire effects, it was stated that fires ay be detrimental or beneficial, depending on the use that is eing made of the land. Indiscriminate killing of timber and growng stock or the destruction of the forest floor is detrimental to ood forestry. On the other hand, killing trees and sprouts is ometimes an objective of range improvement, so at least to stocken, fire appears to be beneficial.

Depending on the objectives of land use and the specific ffects desired, fire may have certain uses. So in using fire all s effects should be considered, including immediate and long-run ains and losses. If burning proves to have a net positive value or a given purpose, the conditions under which the beneficial efects are obtained should be carefully determined and a prescripion written as to how the burning should be done and controlled. aphazard burning has no place in management.

Fire, as a useful tool, is not recommended in Missouri by onservationists for any purpose at present. The use of fire is evertheless a field that must neither be approached lightly nor ith a closed mind. Local residents have used fire for a century nd are still using it.

Obviously these people believe they have found something eneficial about woods burning--at least beneficial to them. Actully some of the claims made for burning, especially some of the emporary benefits, cannot be disputed. This is not to say that n the long run it is a good practice. However, woods burning is eing conducted as a practice by residents and it needs to be losely evaluated. The issue can neither be disposed of by ignorng it nor by avoiding it. Moreover, where the purpose of woods urning is not being served, it is a responsibility of research nd administration to find and promote alternative practices.

As in the study of fire effects, one problem is common to ll aspects of controlled burning: If consistent results are to e obtained from burning, the fire must be of known intensity and ehave according to plan. Successful prescribed burning therefore s very closely tied to the problems in fire behavior.

Range Management

The practice of woods range burning is controversial between oresters and farmers. Although burning may sometimes favor forage ver trees, it is a very doubtful means to obtain permanent range mprovement by itself. Based on what is known to date, burning of

woods ranges is not a practice to be promoted. It is a practice that needs study and evaluation. It has been suggested that burning may be a means to control the encroachment of redcedar on the "glade" ranges. Although this objective can perhaps be achieved, burning may also cause severe deterioration of forage plants and site especially if proper grazing management is lacking. Emphasis in such studies should be on the effects of fire rather than on seeking a use for fire.

Silvicultural Practice

Practically no prescribed burning has been done in Missouri as a silvicultural practice. This is partly because its use has not been proven necessary or beneficial and partly because almost all the forest has been burned anyway. The main consideration now is to control indiscriminate burning. This does not preclude the possibility, however, that fire under proper control may be a useful tool. Possible uses of fire as a silvicultural tool may include (1) seedbed preparation, (2) control of unwanted species, and (3) control of insects and diseases. Carefully controlled experimental fires are necessary in order to test these and other possible uses and to prescribe how the burning can best be done if any of these uses prove desirable.

Wildlife Habitat

Fire has been used experimentally to maintain or improve wildlife habitat in various parts of the country, though not in Missouri. This use of fire is also controversial and involves the objectives of integrated land management. It may have no value for the species of wildlife present in Missouri and none has been suggested. The problems that may arise would necessarily be worked out with game managers and fire-control officers. However, as in other uses of fire, research to determine the effects of fire and the determination of suitable burning conditions are basic to this problem.

Research Priority

(See table 7, page 53)

In the present stage of fire control and forest management in Missouri, prescribed burning has very little importance. Experimental tests of its use in the regeneration of pine, range management, and reduction of special fuel accumulations may be desirable on a very small scale. It is more important at this time to stop indiscriminate, uncontrolled burning. The evaluation of current uses of fire, however, is of high importance (table 7, problem 1) and is to be included in the research program.

This problem could be included with Fire Effects or with Fire Prevention Problems. It is included here because it typifies the present need for work in uses in this area. There is urgent need for all forest officers dealing with local residents to possess unbiased facts about the common uses of fires.

Problem 2 could also be listed with Fire Behavior Problems, and from the standpoint of correlating fuel and environment with fire, behavior will receive much attention. Only the difference in viewpoint separates it from problem 2, table 3.

LITERATURE CITED

(1) Decker, Wayne L.
1952. Monthly precipitation in Missouri, climate atlas of Missouri No. 1. Univ. of Mo. Agr. Expt. Sta. Bul. 572.

(2) King, D. B., Roberts, E. V., and Winters, R. K.
1949. Forest resources and industries of Missouri. Univ. of Mo. Res. Bul. 425.

(3) Krusekopf, H. H.
1953. One-fourth of Missouri classed as stony land. Missouri Univ. Farm News Service (43), No. 34.

(4) U. S. Dept. of Agriculture - Forest Service
1956. Glossary of terms used in forest fire control. Agr. Handb. 104.

APPENDIX

Table 1.--Fire-prevention problems

Forest fire problem	Studies in progress	Studies planned	Best handled by:
VERY HIGH OVER-ALL IMPORTANCE			
1. Find effective ways to present information on fire effects, damage appraisals, land use, and related subjects to make it more useful in fire-prevention programs.	none	none	cooperat
2. Assemble facts and carry out or stimulate research to find additional information on which to base practical land use recommendations.	minor	none	station
3. Find out attitudes of residents toward woods burning and forest management and develop better means to secure desirable changes in the attitudes of uncooperative residents.	minor	none	cooperat
4. Find methods to evaluate, and evaluate the over-all fire-prevention program, the effectiveness of fire-prevention personnel and the receptiveness of residents.	minor	none	station
5. Find practical alternative practices to obtain desired results of burning without the accompanying damages of fires.	major	none	cooperat
MEDIUM OVER-ALL IMPORTANCE			
6. Evaluate needs for and methods to reduce heavy accumulations of fuel resulting from logging, T.S.I. herbicide treatments, and fire damaged stands.	none	none	station

Table 2.--Fire-effects problems

Forest fire problem	Studies in progress	Studies planned	Best handled by:
VERY HIGH OVER-ALL IMPORTANCE			
1. Determine the physical effects and predict the effects of fires of various intensities and behavior patterns under various fuel and weather conditions: on vegetation and forest floor.	major	minor	station
2. . . . . .on soil fertility, physical structure, and erosion.	minor	none	cooperation
3. . . . . .on soil moisture and watershed value.	minor	none	cooperation
4. Evaluate the damages and benefits caused by given fires based upon the physical effects of fires under various burning conditions, behavior patterns, and types of vegetation.	none	none	cooperation
HIGH OVER-ALL IMPORTANCE			
5. Determine the physical effects and predict the effects of fires of various intensities and behavior patterns under various fuel and weather conditions: on microclimate affecting forest fuels.	none	none	station
6. . . . . .on wildlife habitat and recreation.	none	none	cooperation
7. . . . . .on resource management and communities.	none	none	cooperation

Table 3.--Fire-behavior problems

Forest fire problem	Studies in progress	Studies planned	Best handled by:
VERY HIGH OVER-ALL IMPORTANCE			
1. Determine basic theories and natural laws relating to chemical, physical, and kinetic aspects of free burning fires.	none	none	regional laboratory
2. Devise techniques and instrumentations to define and measure characteristics of fires that create problems of prevention and control.	none	none	regional laboratory
3. Determine the variation in quantity and physical characteristics of forest fuels by cover types, stand age and density, aspect, slope, burning and cutting history, season, and time.	major	none	station
4. Determine rates of production of new fuels and deterioration of old fuels in various stands and past histories to determine fuel buildups and points of stabilization under various types of cover and types of uses.	major	none	station
5. Determine local relationships between weather and fuel moisture for various kinds, quantities, depths, locations, and sizes of fuels.	minor	none	station
6. Determine effects of local cover and topography on modifications of the direction, strength, and variability of prevailing winds.	minor	none	station
7. Determine the relationship of upper atmospheric conditions to surface phenomena which influence fuel, environment, and unusual fire behavior.	none	none	regional laboratory
8. Determine the relationship of variations in fuel, fuel moisture, temperature, air movements, slope, exposure, season, and time with ignition, spread, intensity, spotting, and crowning of fires.	none	major	regional laboratory
HIGH OVER-ALL IMPORTANCE			
9. Develop improved methods for rapid determinations of the temperature and moisture of fuels in place.	minor	none	regional laboratory
10. Determine optimum exposure for weather instruments to best represent field conditions.	none	none	station
MEDIUM OVER-ALL IMPORTANCE			
11. Determine the characteristic moisture regime and strength and gustiness of winds associated with common wind patterns which prevail during the fire seasons.	minor	none	station

Table 4.--Fire-danger-rating problems

Forest fire problem	Studies in progress	Studies planned	Best handled by:
VERY HIGH OVER-ALL IMPORTANCE			
1. Devise a coordinated plan for improved fire-danger measurement and rating applicable to the central states.	none	major	station
2. Incorporate the correlation of various fuel and environmental factors with fire behavior into a danger-rating system.	none	major	regional laboratory
3. Devise a better means of measuring the resistance of a fire to suppression and control.	none	minor	regional laboratory
4. Correlate resistance to suppression with suppression requirements and integrate with the danger rating.	none	minor	station
5. Determine and evaluate correlation of Central States Danger Meter ratings with occurrence and fire behavior.	major	none	station
6. Evaluate other danger meters to determine possible use in central states.	minor	none	station
HIGH OVER-ALL IMPORTANCE			
7. Devise a method to rate the buildup of fire danger during the periods of drouth.	minor	none	station
8. Devise a method to rate the over-all severity of fire seasons.	minor	none	station
MEDIUM OVER-ALL IMPORTANCE			
9. Develop basis for rating local causative agencies as a fire-danger factor.	none	none	station